A novel and efficient mortar strategy for multi-physics multi-domain simulations in subsurface applications

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Abstract:

Accurate modeling of subsurface engineering applications often requires the simulation of multiple physical processes simultaneously occurring in different parts of the domain. An effective approach may rely on decomposing the overall domain into subdomains, where only the physical processes of major interest are actually simulated, each one with the most effective computational grid and discretization method. To this aim, it is necessary to equip the multi-physics simulator with appropriate mesh-gluing algorithms, which can handle non-conforming subdomains with hanging nodes and intersecting interfaces. The mortar method is an effective technique for enforcing the continuity in a weak sense of a scalar or vector variable field across interfaces by introducing integrals of basis and test functions defined on different meshes. However, the exact numerical evaluation of mortar integrals for arbitrary 3D grids can be a very challenging task, involving the use of complex computational geometry tools.
In this work, we introduce a novel approach with the aim at simplifying the implementation and computational effort required by the mortar method, while preserving its accuracy. The idea is based on developing an approximate quadrature algorithm that replaces standard geometric projections with mesh-free interpolations using radial basis functions. The proposed strategy turns out to be particularly effective as the number of quadrature points increases. Benchmark results show that the proposed method maintains the accuracy and convergence properties of the classical mortar method at a lower cost, also in complex 3D geometries. Numerical experiments dealing with multi-physics and multi-domain simulations in groundwater multi-aquifer systems and coastal transitional environments are presented to support the effectiveness of the proposed approach.
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GReS: A novel multi-physics multi-domain computational tool for geomechanical simulations

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Abstract:

It is very well-known that the prediction of the geomechanics plays a crucial role for a proper management of underground resources, involving multiple physical processes, such as fluid flow, poromechanics, fault activation, thermal flow, and chemical reactions, that can take place simultaneously with multiple time and space scales. Despite a lot of work has been already done for the analysis and simulation of individual subsurface processes, research is still very active in the attempt of coupling geomechanics with other relevant phenomena at the proper scale, from both a numerical and a physical point of view.

GReS is a novel open-source modular platform, specifically designed with the aim at contributing to the development and prototyping of numerical algorithms for fully coupled multi-physics multi-domain geomechanical applications. The idea is to partition the overall computational domain into possibly non-conforming subdomains where different physics and discretization schemes can be used. The code is based on a high-level programming platform (MATLAB) that should lower the entry barrier for new users and developers, as well as the effort for implementing and testing innovative numerical algorithms. Moreover, the modular structure of the code encourages contributions from different developers at variable levels, from the implementation of new physics and discretization schemes to specific algorithms to accelerate the linear and non-linear solver. Despite being primarily conceived as a prototyping platform, GReS wraps low-level advanced linear algebra packages to combine simplicity with fair efficiency.

In the present communication, we will introduce the GReS concept and its current development state, including advances to the mortar algorithm used to transfer the information among non-conforming subdomains with independent meshes. Basic benchmarks will be presented to show the current code's potentials, along with some ideas for future developments.

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